



## **Spatial configuration of plot systems and urban diversity: empirical support for a differentiation variable in spatial morphology**

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## SPATIAL CONFIGURATION OF PLOT SYSTEMS AND URBAN DIVERSITY:

Empirical support for a differentiation variable in spatial morphology

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## ABSTRACT

The central variables in any urban model are distance and attraction. Space syntax research has contributed to the development of new geometric descriptions and measures of distance that have broken new ground, not least when it comes to capturing pedestrian movement. However, the description and measurement of attractions has not been central to the field.

In this paper we extend measurement of attractions to the variable of differentiation. Earlier empirical studies have shown strong indications that there is a correlation between the degree of land division into plots (parcels) and the diversity of socio-economic content, such as residents and economic activity (Marcus et al., 2017; Cantarino & Netto, 2017). Building on this, we present results from an extensive empirical study of Stockholm, in the aim to pave the way towards a spatial variable of differentiation in spatial morphology, with direct impact on socio-economic diversity. The investigation concerns a correlation analysis between, on the one hand, measures of the configuration of plot systems, and on the other hand, categories of economic activity, measured using Simpson Diversity Index.

Special attention has been paid to the demands in studies of this kind for close scrutiny of, on the one hand, the definition of the urban scale the study concerns, and on the other hand, the categorisation of economic activity related to this. Diversity in economic activity can be found at different urban scales. For instance, on the district level, the retail category 'clothes' may be part of creating diversity together with 'food' and 'computers', while on the street level, we may find retail related only to 'clothes', implying no diversity. In addition, on the city level, areas that have variety of basic services (retail, public and cultural facilities), but homogeneous in terms of retail categories, can be also considered as generally diverse. Hence, the question 'diversity of what' and 'diversity on what urban scale', and sensitive categorisations in accordance with this, are central issues, for this study.

The twofold aim of the paper includes first, presenting an overview of complex issues behind diversity concept with the focus on categorisation and scale, and second, empirical studies that support the proposed impact of variable of differentiation on urban diversity.

## KEYWORDS

Spatial configuration, Plot systems, differentiation, diversity, economic activity

## 1. INTRODUCTION: A THEORY OF SPATIAL CAPACITY

The central variables in any urban model are distance and attraction (Wilson, 2000). Space syntax research has contributed to the development of new geometric descriptions and measures of distance that have broken new ground, not least when it comes to capturing pedestrian movement (Hillier & Iida, 2005). However, the description and measurement of attractions has not been central to the field.

In an earlier paper we interpreted attractions as additional variables of spatial form to distance in the form of density and differentiation, where the first was related to buildings and the second to plot systems (Marcus et al., 2017). In this paper we specifically address the far less studied variable of differentiation. Earlier studies have shown strong indications that there is a correlation between the degree of land division into plots (parcels) and the diversity of socio-economic content, such as residents and economic

activity (Marcus et al., 2017; Cantarino & Netto, 2017). Building on this, we here present results from an extensive empirical study in Stockholm, aiming to pave the way towards a spatial variable of differentiation in spatial morphology, with direct impact on socio-economic diversity. The investigation concerns a correlation analysis between, on the one hand, measures of plot systems configuration, and on the other hand, diversity models of economic activity.

The origin of much debate on diversity in cities is of course the writings of Jane Jacobs, for whom diversity was the central theme throughout all of her texts on cities. Most famously it is spelled out in 'the Death and Life of Great American Cities' and the four conditions for generating diversity in cities that she famously proposed in that book: more than one primary function; short blocks; buildings of varying age; and dense concentration of people (Jacobs, 1961). Of these, as we shall see, we will actually find the condition buildings of varying age to be, perhaps a bit surprisingly, the most promising from our current perspective of the need to develop a measure of differentiation for our model (Sayyar & Marcus, 2013). The reason is that while the condition more than one primary function certainly has a strong influence on the degree of diversity in cities, it rather deals with pure programming of diversity than having any obvious connection to spatial form of the kind that we are looking for here. The notion of short blocks, on the other hand, rather deals with accessibility, or quite exactly the configuration of cognitive distances dealt with in space syntax theory as discussed above. Finally, the notion of dense concentration of people clearly concerns the idea of density in general and as such has already been thoroughly discussed (e.g. Stähle et al., 2005; Berghauser Pont & Marcus 2014). The notion of buildings of varying age, on the other hand, seems principally different from the others and at first sight presents itself, perhaps, as the one of both least theoretical interesting and least practically applicable – how do we plan cities with buildings of varying age or, for that matter, build a theory around such a thing. However, that is exactly what we shall attempt.

The trap here is to cling to the idea of buildings as things rather than as processes. A shift to the latter implies a shift from the spaces that buildings create to the spaces in which buildings evolve, that is, the different domains defined property rights that we call plots. These are spaces that are institutionally defined rather than physically defined, but even so they undoubtedly represent a central and common category of spaces in cities. If we start to think about it we realise how fundamental such division of space into several separate spaces is in any architectural endeavour – what is architecture if not the art of dividing space by walls – where the primary rationale behind this exactly is the aim to generate diversity, that is, generate discrete spaces for separate and different categories of 'things' or activities; this clearly is the major rationale behind the division of buildings into separate rooms for instance.

It therefore seems well founded to see the horizontal division of land, whether defined physically or institutionally, as a fundamental spatial technique whereby one can support an increase in differentiation in a similar manner to how the vertical addition of floor-space is a fundamental technique in increasing density (Marcus et al., 2017). If we more specifically introduce this concept to a model of urban spatial form, we can make the following argument. The particular domain of the plot, as a piece of land defined by a specific set of property rights, represents the presence in the city of an actor in the form of its owner or proprietor or the like, which, furthermore, entails a very precise location of the activities of that actor in urban space (Marcus, 2000; 2010; Bobkova et al., 2017a; 2017b). It is within this particular domain the specific actor is free to act, as long as keeping within the framework set by different institutions, for instance, the local planning regulations or the particular property rights of the concerned piece of land.

Such actors, furthermore, will normally develop a particular strategy for the further development and maintenance of their property. An area with comparatively many plots therefore seems to have the potential to carry more such actors and thereby more strategies for the development and maintenance of its plots than an area with comparatively few plots, and this, most likely, will also imply a greater diversity of such strategies. In the end, such an area seems to have the potential to more easily develop a diverse content than the area with comparatively few plots and hence few actors and strategies. Consequently, it seems to be exactly this division of land and the subsequent creation of potential diversity in actors and strategies that over time can generate a greater variety in the building stock, that is, Jacobs' notion of buildings of varying age.

It is this hypothesis that makes us believe that we in the number, shape, size and configuration of plots can identify a variable of spatial form with a direct relation and influence on urban diversity. Moreover, we propose that the number of plots in an area can be called the spatial capacity of that area, that is, the capacity to carry differences, where a high capacity creates a greater potential for a heterogeneous content, while a low capacity does the same for a more homogenous content (Marcus, 2000; 2003; 2010; Bobkova et al. 2017ab). Obviously other factors like land-use regulations or other spatial variables, such as street centrality and building density, certainly can override the effect of the spatial form of plot systems here,

but what we are trying to isolate in our study is the particular influence of this variable on urban entities or processes.

In the following we will present an empirical study that relates different kinds of diversity as dependent variables to the independent variable of differentiation measured as accessibility to plots. The outline of the paper is as follows. In the next two sections, theoretical complications behind measuring socio-economic diversity will be presented, with particular focus on the issues of scale and categorization. These sections will provide the support for the choices made for the empirical tests presented next. Thereafter, we will present a methodological overview of the empirical study, including: (1) how to measure the dependent variable of socio-economic diversity, (2) how to measure the independent variable of spatial differentiation, (3) how to address the issue of scale, (4) how to construct the statistical models that allow for isolation of the differentiation variable, and (4), the description of statistical tests. Thereafter the results from the study will be reported and, in the conclusion finally, the results will be discussed in relation to the theories earlier introduced with suggestions for future research.

## 2. DIVERSITY AND SCALE: WHAT WE MEAN BY SCALE

The term scale is used in many fields and is often interpreted quite differently in one discipline from another. There are also many related concepts like; level, resolution, extent, and hierarchy, often used as replacements or synonyms (Gibson et al 1999). In studies on cities, not least, there is a wide range of references to scale, which also have given rise to a variety of categorisations, such as ‘local-global’, ‘micro-meso-macro’, ‘neighbourhood-district-city-region’. However, these terms are by rule vague due to their intrinsic relative nature. They typically are defined in relation to each other for a particular case and what is understood as, for instance, ‘local’ varies from city to city. Together this makes scale one of the most easily confused concepts in the study of cities. This is problematic since choice of scale fundamentally influences both analysis and interpretation in any study of urban modelling or spatial analysis.

According to Mike Batty, we by scale basically mean two things: “the level of resolution at which we observe the city, which is essentially map scale, and the level of functional differentiation that takes place in different sizes of location or city” (Batty, 2005). That is, scale can concern resolution or size but these two are easily confused. All the categorisations listed above, for example, such as the highly relative macro-meso-micro set, typically refer to resolution but can easily be taken for categories of size, not least when applied in concrete urban settings. For instance, when speaking about ‘neighbourhood’, as a particular scale in relation to ‘district’ or ‘city’ scale, we speak about a particular resolution of cities, that is, we zoom in on an area so that we can identify more detail about what is going on there, but this does of course not make the city where we do this smaller or larger. Still, it is an operation where it is easy to begin thinking about the particular neighbourhood as a small city, that is, that we have changed size of the city, but this is obviously not the case.

The immediate risk here of slipping into some overarching, grander or more abstract city that easily takes on life of its own, is encouraged by the fact that we often speak of scales as hierarchies. In Alan Wilson’s words: “Scale is a form of hierarchy and clarity of vision in this respect is critical” (Wilson 2000). A typical case is the categorisation of urban phenomena into micro, meso and macro scale, which conceptually imply, even though we know that it is not true, that there is a series of cities, so to speak, on top of each other. Once again, upon reflection we instantly realise that this is nonsense, but even so, conceptually the slip has already been made and it is difficult to keep in mind that we do not really mean what we say. For instance, when the introducers of the new spatial economy talk about centrifugal and centripetal forces on the concentration of economic activity in cities (Fujita et al., 1999), we are enticed to envision these as some kind of macro scale forces hovering over cities. In reality, these are forces that analytically are identified on an aggregated macro scale, but that is certainly not where they are acted out. On the contrary, such forces, while leaving distinct traces on aggregated level, are by necessity rooted in human everyday activity on the micro scale.

Moreover, we also need to keep our vision clear concerning what entity it is that we discuss the scale of. Following Wilson (2000), we can say that spatial analysts face the question of resolution in three ways: “entities that are components of systems of interest have to be defined and categorised; many of them have to be located in space; and their behaviour has to be described over time”. This leads to three aspects of scale necessary to decide on: “sectorial (number and breadth of categories), spatial (size of area units within which entities are to be located) and temporal (length of time units which provide the basis for longitudinal description and analysis)”. Temporal resolution constitutes a big issue in itself in that most spatial analyses simply leave out the time dimension, giving rise to the typically static descriptions of cities that we have grown accustomed to. In principle, these are highly unrealistic and for most uses risky



to draw conclusions on, however, that is exactly what we do in most studies of cities. The sectorial and spatial aspects, on the other hand, are in most studies there. However, it is important to keep track of how both size and resolution can vary in both, once again, creating many reasons for confusion. Sectorial entities, that is, phenomena or activities that we want to locate and analyse in space, for instance businesses, can vary in size, that is, we can have large businesses and small businesses, which does not imply variations in resolution. However, we can certainly also have variations in resolution of sectorial data, for instance, in how we categorise size in businesses. We can do that with high resolution using, for instance, absolute number of employees, or with a lower resolution where we, for instance, group the number of employees into bundles.

If we want to discuss spatial size, on the other hand, we need another way of entry. First of all, we need to be absolutely clear about what it is that we want to analyse the size of and, second, from what point of view we define size. For instance, if we want to compare the size of one neighbourhood to another, in principle comparing one spatial unit to another, we can of course do this simply by comparing the size of the individual units, for example by measuring their area. Such comparison, however, is in most cases likely to be rather uninformative and quite arbitrary. More interesting, it seems, is to measure size in some systemic way, not least given the predominance of systems views of cities in contemporary research. This would concern to somehow measure the size of impact or importance of the individual spatial unit on the system as a whole, for instance, the role of the individual neighbourhood on the whole district or city. It could, for example, concern the relative distance from the individual spatial unit to all other spatial units, where a short such distance could be argued to represent a strategic location and be interpreted as one way of measuring the individual unit's systemic size. Moreover, such analysis could be conducted within different distance radii of the individual spatial unit, for instance set by metric distance. Such radii could, in turn, be used as definitions of analysis at different scales, but now we really need to keep track of what we are doing. Are these definitions of scale of size or scale of resolution? Most interestingly, they are definitions of scale of size and therefore extremely useful. The scale of resolution is defined by the choice of spatial unit, not by radii as we have defined it. These radii, therefore, open for the valuable possibility to compare the individual spatial units' role and function at different scales of size!

As already touched upon, such comparison of role and function at different scales of size is absolutely central for a proper understanding of how cities work. For instance, an area detected as relatively homogeneous at one scale may prove to be quite heterogeneous at another. Moreover, it is not least enquiries of overlapping scales, that is, where localities simultaneously perform on different scales and thereby are reinforced or weakened, that prove critical for our understanding of urban phenomena and processes. Concerning this critical interplay between scales, Jacobs, for instance, took a critical position to planners' ability to establish self-governing neighbourhoods, given their stubborn focus on the neighbourhood scale and negligence in putting it in relation to the over-all city scale for a proper understanding of the functioning of neighbourhoods. As discussed thoroughly elsewhere, Jacobs was probably the first to argue the need of a consistent systems view of cities,<sup>1</sup> famously answering her own question: What kind of a problem is a city?: "Cities happen to be problems in organized complexity" (Jacobs, 1961).

To summarise, proper spatial analyses of urban phenomena in most cases necessitate having a multi-scale approach that covers, for instance, micro-, meso- and macro-studies, in order to get the full perspective and especially there is a need to move between scales looking for interrelations and reinforcements or lack thereof. More specifically, if we accept the presumption in urban economics that diversity leads to regional urban growth (Glaeser et al., 1992; 2001), the issue of what scale we are referring to when we speak of diversity in the city is critical. Most likely such growth is due to interaction between scales more than anything. Not least, this is important for policy and concrete interventions in urban planning and design. For instance, urban design is normally understood to concern primarily the local scale but through better knowledge about the interaction between scales urban design can perhaps be proven to indirectly influence also other scales. Conversely, to achieve aims on the local scale, interventions on other scales might be necessary. In this regard, hierarchical analysis covering neighbourhood, district and city scale, suggests itself as critical.

To address the issues described above we measure our variables at several scales, and importantly, we measure them as accessibility through the movement network, for instance, as accessibility to plots or economic activity<sup>1</sup>, in line with earlier developments of space syntax analysis into place syntax analysis

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<sup>1</sup> For the accessibility analysis we use Place Syntax Tool, which concerns new methodologies and software that opens for analysis not only of different kinds of accessibilities in the street network in itself, but also analysis of the accessibility within the network to different forms of attractions, for instance, residents or retail. Place Syntax analysis is a generic form of analysis, why we may choose to analyse the accessibility to particular socio-economic





(Ståhle et al., 2005). To address the local scale of the independent variable, we choose to measure accessibility to plots within a 500m radius, which is commonly recognized as an approximate distance for the willingness to walk (Gehl, 2010). To address the meso and, to a certain extent, the global scale, we also add measures at a radius of 1000m and 2500m.<sup>2</sup> For the dependent variable, scale is addressed by applying two different categorisations, where the first is aimed to broadly capture diversity in economic activity at the urban scale, and the second to capture more specific diversity in economic activity (retail) on the district level. The problem of categorisation in diversity is discussed in the next section.

### 3. DIVERSITY AND CATEGORISATION: WHAT WE MEAN BY CATEGORISATION

Fundamental for any type of spatial analysis is the development or choice of a satisfying system of classification (Harvey 1969; Wilson, 2000). As in most empirical studies, spatial analysis studies present a rich set of individualities that needs to be sorted one way or another to be accessible for adequate study, what was called sectorial entities by Wilson above. Such a classification depends on the aims of the enquiry, where the very same individuals can be sorted very differently depending on these aims. Hence, the development of an adequate classification system requires great precision. At the same time, this has proven to be one of the most difficult tasks in spatial analysis. Generally speaking, classification is regarded as “the basic procedure by which we impose some sort of order and coherence upon the vast inflow of information from the real world”, and [It is] “regarded as a means for structuring reality to test hypothesis” (Harvey, 1969). This implies that the adequacy of a classification system cannot be evaluated independently of the purpose of the study. The importance of a primary question or a presupposed hypothesis is often stated, in order to have a proper interrelationship between theory and classification (Harvey, 1969). In extension of this, as emphasised by Wilson, one should be aware that: “there is no absolutely right way to do categorization” (Wilson, 2000).

In our particular case, the need of a clear classification arises from the aim of analysing and measuring diversity in urban space. The principles behind the choice of classes, the number of classes, as well as their attributes, will all have crucial effects on the final diversity values. For example, if we measure the diversity in an area concerning primary functions, for instance, divided into residential and working populations, this will be very different from the same areas diversity concerning economic sectors, such as official, commercial and industrial sectors. Moving down the hierarchy, measuring the diversity in, for example, the commercial sector, and more specifically retailing, which, for instance, can be classified and sorted based on the type of goods offered, such as clothes, shoes and furniture, this will yield different values yet. This means that an area can have a high diversity and a low diversity at the same time, all depending on the classification used.

In this paper we will use two types of diversity classification that is based on OpenStreetMap and extracted from OSM coding system. The reason of using OpenStreetMap, is justified by the possibility to compare differences between cities within one country or in several countries. Our current study focuses on analysing one city of Stockholm, but has the ambition to be potentially extended to other cities as a part of larger research project. OSM categories are based on point data and include such categories as retail and services, food, banks, hotels, health, education, public facilities, culture and sports. It also proposes more fine-grain categorisation of retail activities, that include food and department stores, clothes, health and beauty, households, furniture, electronics, sport and stationary and books. Based on this data we propose to introduce to kind of diversity: diversity on the city level (further referred to as general diversity), and retail diversity on district or street level. The choice of retail as a measure of local scale diversity, is justified by the fact that it is generally recognized to indicate the intensity of pedestrian-related economic activities in cities (Scoppa & Peponis, 2015; Sevtsuk, 2014; Sevtsuk, 2010; Sevtsuk, 2010; Krafta, 1996). Both diversity indices are calculated using Simpson Diversity Index, that is commonly used in urban studies (Talen, 2008), and can be easily translated into accessibility measure.

### 4. METHODOLOGY

The general methodological steps include measuring the dependent variable of diversity (1), measuring the independent variable of differentiation (2), constructing sub-models by controlling variables of street

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attractions, such as residents or retail, but it can also be applied for building density analysis, transforming such density measures from area-based to location-based measures. PST is a plugin application for the desktop software Mapinfo that combines space syntax with regular accessibility analysis in one tool.

<sup>2</sup> Higher radii are not added to the analysis, if larger radii are applied to accessibility analysis, the differences between urban areas even up, due to specificities of the measure.

centrality and building density (3), linking data on dependent and independent variables in one model (4), and finally, statistical analysis of co-variation between independent variable of differentiation and dependent variable of diversity (5).

### Step 1. Measuring general and retail diversity

The dependent variable of diversity is measured using Simpson Diversity Index that is translated into an accessibility measure. Simpson Diversity Index is a generally recognized indicator for measuring diversity of urban activities (Talen, 2008), and our question at hand is what categories should be included. As described earlier, it is proposed to use two categorisations of diversity based on OSM data, that address two urban scales: general diversity and retail diversity. General diversity (referred further as  $D_{\text{general}}$ ), includes all kinds of basic urban services (excluding offices) that are more evenly distributed across the city, and retail diversity (referred further as  $D_{\text{retail}}$ ) is usually associated with the intensity of pedestrian-related economic activities in vital city centers (Scoppa & Peponis, 2015; Sevtsuk, 2014; Sevtsuk, 2010; Sevtsuk, 2010; Krafta, 1996).

Two diversity indices ( $D_{\text{general}}$  and  $D_{\text{retail}}$ ) are calculated and measured as accessibility within a 500m radius. First, accessibility to each separate category is calculated, second, accessibility to the total number of categories is calculated, and then the resulting numbers are used to calculate Simpson Diversity Index ( $D = \sum (n/N)^2$ )<sup>3</sup>, where  $n$  is the number of activities within each category, and  $N$  is the total number of all activities.

### Step 2. Measuring independent variable of differentiation.

The differentiation variable can in more simple terms be described as plot size, or, in accessibility terms, as the accessible number of plots, because if plots are smaller, they typically are many (Bobkova, 2017a). Hence, the differentiation variable is measured as the absolute number of plots accessible from every single address point, across several scales or radii, according to the discussion above: 500m, 1000m and 2500m walking distance, and is further referred to as the accessible number of plots or accessibility to plots ( $A_{\text{plot}500}$ ,  $A_{\text{plot}1000}$  and  $A_{\text{plot}2500}$ ).

### Step 3. Constructing sub-models by controlling for street centrality and building density

To evaluate how the variable of differentiation is related to the two different kinds of diversity, two other variables of spatial form (street centrality and building density) have to be controlled for. Typologies of both streets according to centrality and buildings according to density has been analytically generated in earlier research that here is used in our selection of locations from which our variables are measured (Berghauser Pont et al., in review) so that these variables remain constant.

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<sup>3</sup> In the Simpson Diversity Index the bigger the value of  $D$ , the lower the diversity. To make it more intuitive the value of  $D$  is subtracted from 1, so the values closest to 1 mean higher diversity ( $1-D$ )



Figure 1. Overview of 4 sub-models (2 street types x 2 density types)

Multi-scalar centrality street types were generated using centroid-based clustering to classify street segments based on their individual betweenness centrality profile through different scales<sup>4</sup> (Berghauser Pont, et al., in review). The cluster analysis resulted in five centrality types, where only observations from two of these ('City' and 'Neighbourhood') have been included in our analysis, because in the other three types economic activity was hardly found at all. The street type 'City' includes street segments of increasing betweenness centrality at higher scales and 'Neighbourhood' has segments with consistently high betweenness across most scales, but dropping clearly at the most local scales (ibid.).

Building density types were developed using cluster analysis (Berghauser Pont et al., 2017), based on two input variables: Floor Space Index (FSI) and Ground Space Index (GSI) (Berghauser Pont & Haupt, 2010), measured within 500m walking distance. The clustering generated six density types, of which two types were selected for our analysis, because, similarly to the two selected street types, only these were associated with a substantial number of economic activities. The two selected density types were 'Dense

<sup>4</sup> For the street types non-motorised street network has been used, betweenness centrality has been measured across several scales from 500m to 5km.



mid-rise’ (the highest combination of FSI and GSI characteristic for city centres) and ‘Compact mid-rise’ (slightly lower FSI and GSI values compared to ‘Dense mid-rise’).

Including these control variables gives us 4 sub-models (two street types x three density types, see figure 1), that allows us to evaluate co-relation between general or retail diversity and accessibility to plots at different scales (figure 1).

#### Step 4. Linking data on dependent and independent variable

A layer of address points for Stockholm is used to join all the components (streets, buildings, plots and activities), and link their properties in one model. The choice of using the address points is justified by the fact that a plot or a building typically can be associated with different street segments. Here, plots and buildings are linked to the streets from where one can enter it, which is represented by the address point (Berghauser Pont et al., in review).

#### Step 5. Statistical analysis.

First, bivariate Pearson’s correlations are run, where accessibility to plots at three scales is correlated both with general and retail diversity. Because our independent variables are highly collinear, multiple regression models are not run, since linear regression for only one variable only would show the similar results as the Pearson’s correlation results. Nevertheless, we still run linear regressions for the sub-models with the highest correlation on the next step, in order to map residual values. They allow to evaluate underpredicted or overpredicted values, if there is any other spatial variable besides plots not included in our analysis, that influences higher or lower diversity in particular area.

### 6. RESULTS OF STATISTICAL ANALYSIS

When general diversity is correlated with accessibility to plots, correlation generally gets higher at higher radii ( $A_{\text{plot}2500}$ ) in sub-model ‘Södermalm’ as well as in street type ‘City’, except the sub-model ‘City + Density type Dense Mid-rise’. In Street type ‘Neighbourhood’ combined with Density type ‘compact mid-rise’, the correlation with plot types gets lower at the lower radii (table 1A).

When retail diversity is correlated with accessibility to plots, correlation generally gets higher at lower radii ( $A_{\text{plot}500}$ ), for all sub-models except ‘Neighbourhood + Compact Mid-rise’ (table 1B).

Model	A.General Diversity			B.Retail Diversity			N (number of observations)
	$D_{\text{general}}$ and $A_{\text{plot}500}$	$D_{\text{general}}$ and $A_{\text{plot}1000}$	$D_{\text{general}}$ and $A_{\text{plot}2500}$	$D_{\text{retail}}$ and $A_{\text{plot}500}$	$D_{\text{retail}}$ and $A_{\text{plot}1000}$	$D_{\text{retail}}$ and $A_{\text{plot}2500}$	
Street type City + Density type Dense Mid-rise	<b>-0,455</b>	0,331	0,149	0,313	-0,030	-0,552	1340
Street type City + Density type Compact Mid-rise	0,184	0,299	0,328	0,163	0,111	-0,015	1234
Street type Neighbourhood + Density type Dense Mid-rise	-0,154	0,035	0,235	<b>0,440</b>	0,072	-0,254	458
Street type Neighbourhood + Density type Compact Mid-rise	0,405	0,390	0,136	0,229	0,371	0,277	349

Table 1. Summary of Pearson's correlations. Higher correlations per sub-model are marked in bold.

We may conclude here, that retail diversity indeed corresponds better to accessibility to plots measured locally, and highlights the location of pedestrian-oriented urban centres found in the city. At the same time, our earlier argument that general diversity is more evenly distributed across the city, is supported by the finding that it is correlated better with accessibility to plots at larger radii. However, any conclusions here are still premature. There is need for further investigation, not least through similar analysis in other cities.

Our key interest is the correlation between the accessibility to plots and retail diversity, because, as mentioned before, retail clusters are often recognised as indicating the location of pedestrian-friendly urban centres. Hence, in the next step we look specifically at the sub-models with the highest correlation between accessibility to plots and retail diversity and then run linear regression models. This is done in order to see if there is a problem with spatial correlation in the data, which cannot be explained by the model. Mapping residual values then allows to see if there are concentrations of observed values on the map that are over-predicted or under-predicted, which would mean that there are other spatial variables in our sub-model that override our explanation of retail diversity through accessibility to plots. Hence, we

proceed and run linear regression analysis for the sub-model 'Neighbourhood + Dense Mid-rise' ( $R^2=0,194$ ,  $p<0,05$ ) and mapping residual values (figure 2).



Figure 2. Map of residuals for two sub-models: Södermalm and Neighbourhood + Dense mid-rise.

The map of residual values (figure 2), shows whether there are any problems of spatial auto-correlation in the data by highlighting the concentrations of under- or over-predicted residual values. Underpredicted values (figure 2, brown), mean that the observed value (retail diversity) in the area is lower than predicted by the accessibility to plots. In turn, overpredicted values (figure 2, green) show that observed values are higher than expected. Yellow areas on the maps (figure 2) show that observed values are relatively well predicted. Clustered areas of over- or underpredicted values are useful for the interpretation of the results, because they highlight the areas where it might be that some other conditions, spatial or other, besides accessibility to plots contribute to higher or lower retail diversity in the area than expected according to our model.

A case of principal interest is that even though retail diversity is generally well predicted by accessibility to plots, a surprising exception is the busy shopping street Birger Jarlsgatan (brown on the map), where diversity is found to be lower than expected. We may therefore conclude that there may be some other condition influencing retail diversity along this street. On closer scrutiny however, we realise that this is a



street for high fashion retail, which again highlights the necessary concern for scale and categorisation. While general diversity of economic activity is unlikely along Birger Jarlsgatan with its high fashion cluster, neither is it very diverse in retail, there are not many hard ware stores around, since most shops carry fashion clothes. However, if we would make an even more fine-grained analysis of diversity, concerning only retail that carry clothes, Birger Jarlsgatan is likely to demonstrate a very high diversity. This discussion is yet premature and calls for further studies, but it draws attention to the central issue of scale and categorisation in studies of diversity.

## 7. CONCLUSIONS

The aim of this paper was twofold, first, to present and test empirically potential link between urban diversity and the variable of differentiation (plots) and second, to present the whole complexity of measuring diversity, that is related to the interconnected issues of scale and categorisation. In order to deal with these two problems, we proposed that scalar issue can be tackled by introducing different kinds of diversity, in our case general (global) and retail diversity (local). In addition, we proposed to correlate it with the variable of differentiation across several spatial scales. In order to control our tests for possible influence of building density and street centrality on the results, we introduced several sub-models, where within each sub-model, these two other spatial variables remain constant.

As it was shown by Pearson's correlations, areas that have higher general diversity values (access to variety of basic services) are indeed better correlated with accessibility to plots at higher radii, while areas that have higher retail diversity values (access to variety of retail services) correlate better with accessibility to plots on lower radii. This finding can further serve as a starting point, to conduct a more extensive study of similar kind, but across several cities.

In addition, when we investigated distribution of retail diversity in more detail, by focusing on one of the sub-models and mapping residual values from linear regression, it was found, that retail diversity of some particular areas cannot be explained by the higher number of plots present in the area. We suggested then, that there is possibly a necessity to introduce diversity measure at even finer scale, by introducing categorisation within one particular kind of retail: fashion stores.

While still far from conclusive, these observations do support our hypothesis that there is an important connection between the number of plots (differentiation variable) and urban diversity; an important finding that calls for further and more comprehensive investigation.

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## Proceedings of the 12<sup>th</sup> Space Syntax Symposium

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